Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava
číslo 3, rok 2009, ročník LII, řada hutnická,
článek č. 1559

Soňa RUSNÁKOVÁ[1], Juraj SLABEYCIUS[1], Ivan LETKO[1], Dana BAKOŠOVA[1], Jan KRMELA[2]

MICROSCOPIC OBSERVATION OF COMPOSITE STRUCTURE AND THEIR DEFECTS

MIKROSKOPICKÉ POZOROVANIE KOMPOZITNÝCH ŠTRUKTÚR A ICH DEFEKTOV

[1] *Faculty of Industrial Technologies in Púchov, University of Alexander Dubček in Trenčín, Slovak Republic, rusnakova@fpt.tnuni.sk*
[2] *The Jan Perner Transport Faculty, University of Pardubice, Department of Informatics in Transport, Studentská 95, 532 10 Pardubice, Czech Republic*

Abstract

This work is orientated to observation of structure composite materials by optical microscope. We chose three types of carbon/epoxy laminate composites with different kind of reinforcement, number of layers and their sequence. During observation we concentrated our attention to transverse fibbers, longitudinal fibbers resin and defects like large hollow, transverse cracks. Longitudinal cracks, delamination, too.

Abstrakt

V tejto práci sme sa zamerali na sledovanie vnútornej štruktúry kompozitných materiálov pomocou optického mikroskopu. Vybraným druhom boli uhlík/epoxidové laminátové kompozity s rôznym druhom výstuže, počtom vrstiev a sekvenciou ukladania. Počas vlastného pozorovania sme sa zamerali na sledovanie pozdĺžnych a priečnych zväzkov vlákien, bublín, rozmerných vákuol, pozdĺžnych a priečnych trhlín a taktiež na delamináciu laminátu.

Key words: composite materials, carbon/epoxy laminate composites, defects

1. Introduction

Composite materials have gained popularity (despite their generally high cost) in high-performance products that need to be lightweight, yet strong enough to take harsh loading conditions such as aerospace components (tails, wings, fuselages, propellers), boat and scull hulls, bicycle frames and racing car bodies. Other uses include fishing rods and storage tanks. The new Boeing 787 structure including the wings and fuselage is composed largely of composites. [1]

Carbon composite is a key material in today's launch vehicles and spacecraft. It is widely used in solar panel substrates, antenna reflectors and yokes of spacecraft. It is also used in payload adapters, inter-stage structures and heat shields of launch vehicles. [2]

The properties of laminate are depending on kind of used fabric, so each producer uses the kind of cloth with different parameters, with various thicknesses and in different total quality of variants. On other hand, second part of laminate effects modification of the final properties of laminates. The viscosities, the additives, which are used to improve processing properties, have important influence to final physical-mechanical properties. So, this all are responsible on final properties of laminate, that are in current technology requirement necessary.

The detection and characterization of the wide range of defects requires a number of specialized non-destructive methods. The proper assessment of defects is essential, particularly in safety-critical structures such as primary and secondary aircraft components, to avoid catastrophic failure. [3]

2. Experimental part

Samples for experimental observation were devided to the kategory on the principle of kind of laminates. During observation by optical microscope we concreted our research to those objects: transverse fibbers, longitudinal fibbers, resin and defects like large hollow, delamination cracks, transverse cracks. Table 1 describes 3 types of carbon epoxy laminates and their composition.

Table 1 Type of composite for microscopically observation

Sample	Type of composite	Kind of fabric	Matrix	Sequence of deposition
1	carbon/epoxy	Fabric - cloth 220g/m^2	Epoxy matrix L285 MGS	6x(0°/90°)
2	carbon/epoxy	Fabric - unidirectional - 140g/m^2	Epoxy matrix L285 MGS	9x(0°/90°)
3	carbon/epoxy	Fabric - unidirectional 220g/m^2	Epoxy matrix L285 MGS	6x0°

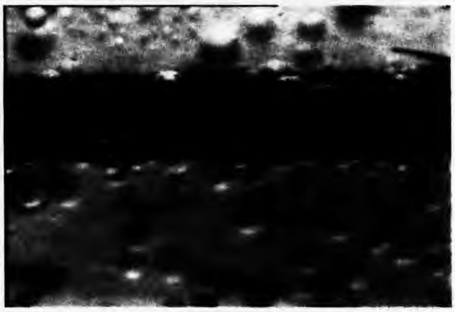

Fig 1 Sample 1, 7x extension

Fig 2 Sample 1, 20x extension

On the Figures 1, 2 we can see cross-section of the sample 1. We can see individual layers of carbon cloth with tabby weave at various extensions. This kind of laminate contains six layers of cloth, which are stored parallel, so is well-marked deviation fibre bundle. We can consider that this kind of defect occurred before processing individual laminate composite. Black points on the figures are large hollows. It can be clearly seen individual fibre bundle in longitudinal direction and fibres in cross-section.

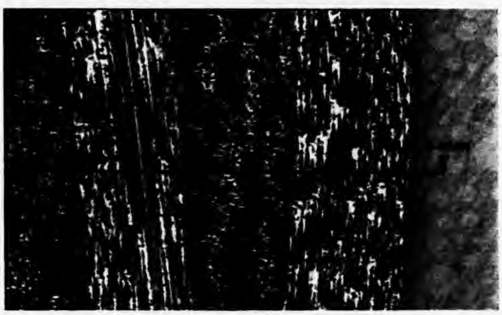

Fig. 3 Sample 1, 100x extension

On the Figures 3 we can observe longitudinal fibbers, transverse fibbers. Black points are wholes, grey colour is resin. Figures 4 depict cross whole sample. On the basic of extensions we can estimate approximately thickness of two layers cloths with resin to value 0,5 mm.

Fig. 4 Sample, 100x extension

Nine layers of unidirectional carbon/epoxy laminate we can see on the Figure 5. Those layers are store over each other. The black points are the large wholes. Figures 6 depict cross whole sample by 100 x extensions. Once again, it can be seen individual fibre bundle of carbon cloth, longitudinal and transverse fibbers and wholes.

Fig.5 Sample 2, 45x extension

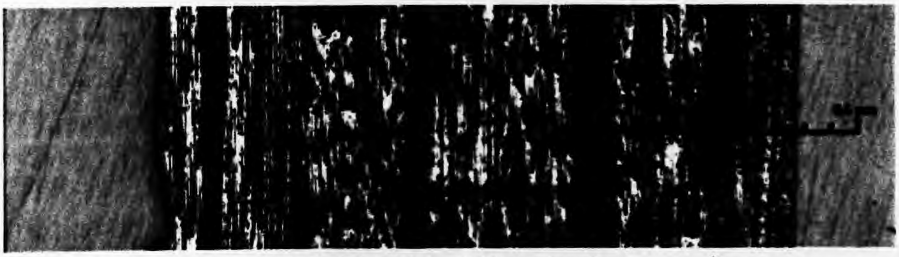

Fig. 6 Sample 2, 100x extension

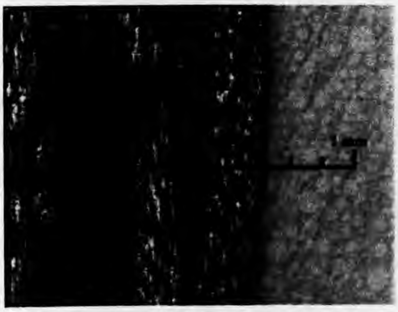

Fig. 7 Sample 3, 50x extension

Figure 7 depicts cross whole sample by 500 x extensions, where we can see from the right side structure: longitudinal fibbers, transverse fibbers, longitudinal fibbers, transverse fibbers and longitudinal. Once again, it can be clearly seen wholes by black colours and resin by green colours.

Delamination is a mode of failure for composite materials. Mode of failure is also known as 'failure mechanism'. In laminated materials repeated cyclic stresses, impact, and so on can cause layers to separate, forming structure of separate layers, with significant loss of mechanical toughness. Individual fibers can separate from the matrix e.g. fiber pull-out.

Composites can fail on the microscopic or macroscopic scale. Compression failures can occur at both the macro scale or at each individual reinforcing fiber in compression buckling. Tension failures can be net section failures of the part or degradation of the composite at a microscopic scale where one or more of the layers in the composite fail in tension of the matrix or failure the bond between the matrix and fibers.

3. Results

The problematic of microstructure and macrostructure of laminate composites is in technical literature very rare and it is described only slightly without experimental results from optical structure of interface individual kind of laminate, dimension of wholes, longitudinal and transverse cracks, deflection fibber bundle from used laminate sequence.

The knowledge of internal structures can be very useful information for designers and technologists to design concreted laminate composites for applications, because on the basic these results they can prevent to unwanted delaminations, cracks ant by this increase durability.

On the basic our experience we can consider, that observation of internal structure is very time consuming evaluation progress of laminate composite, because it is very hard to differentiated individual structural components, designate their line, various inhomogeneities, those are during technology processing by hand lay up very often.

Laminated composite materials offer a number of potential advantages in the aerospace field, particularly in safety-critical structures such as primary and secondary aircraft components. The presence of several types of defects such as voids, inclusions, debonds, improper cure, and delamination are almost common during the manufacture and use of composite materials.

Acknowledgement

The authors are grateful to the Ministry of Education of Slovak Republic for financial support of the project KEGA 3/5178/07.

References

[1]. BAR-COHEN, Y., CHANG, Z.: Characterization of defects in composite material using rapidly acquired leaky lamb wave dispersion data. NTD, Vol.3, No.9, 1998.

[2]. Ray, B.C.: Evaluation of Defects in FRP Composites by NDT Techniques. Journal of Reinforced Plastics and Composites, Vol. 26, No. 12, 1187-1192, 2007.

[3]. Dasgupta, A., Wan, Y., Sirkis, J. S., Singh, H.: Micromechanical investigation of an optical fiber embedded in a laminated composite. Proceedings of SPIE Vol. 1370, 1990.

Reviewer: Prof. Dr. Ing. Jaroslav Sojka, VŠB –TU Ostrava